IS 8407 (2010): Acceptance Conditions for Gear Hobbing Machines - Testing of the Accuracy [PGD 3: Machine Tools]

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IS 8407 : 2010
ISO 6545 : 1992

भारतीय मानक

गियर हॉबिंग मशीनों के लिए स्वीकृति अनुकूलता — परिशुद्धता परीक्षण

(पहला पुनरीक्षण)

Indian Standard

ACCEPTANCE CONDITIONS FOR GEAR HOBBING MACHINES — TESTING OF THE ACCURACY

(First Revision)

ICS 25.080.20

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NEW DELHI 110002

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Machine Tools Sectional Committee, PGD 03

NATIONAL FOREWORD

This Indian Standard (First Revision) which is identical with ISO 6545 : 1992 'Acceptance conditions for gear hobbing machines — Testing of the accuracy' issued by the International Organization for Standardization (ISO) was adopted by the Bureau of Indian Standards on the recommendation of the Machine Tools Sectional Committee and approval of the Production and General Engineering Division Council.

This standard was first published in 1977. This revision has been taken up to align it with the latest edition of ISO Standard.

The text of ISO Standard has been approved as suitable for publication as an Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'.

b) Comma (,) has been used as a decimal marker while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

c) Some dimensions appear in 'inches' in the International Standard besides in metric systems, while in Indian Standards, the current practice is to give metric values only.

The technical committee has reviewed the provisions of the following International Standards referred in this adopted standard and has decided that they are acceptable for use in conjunction with this standard:

International Standard	*Title*
ISO 230-1 : 1986[1)]	Acceptance code for machine tools — Part 1: Geometric accuracy of machines operating under no-load or finishing conditions
ISO 701 : 1976[2)]	International gear notation — Symbols for geometrical data
ISO 1328 : 1975[3)]	Parallel involute gears — ISO system of accuracy

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1) Since revised in 1996.
2) Since revised in 1998.
3) Since revised as ISO 1328-1 : 1995 and ISO 1328-2 : 1997.

Indian Standard

ACCEPTANCE CONDITIONS FOR GEAR HOBBING MACHINES — TESTING OF THE ACCURACY

(First Revision)

1 Scope

This International Standard specifies geometrical tests and practical tests, with reference to ISO 230-1 and also kinematic tests (accuracy of the transmission of motion) for general purpose and normal accuracy gear hobbing machines, with vertical or horizontal spindle. This International Standard also gives the terminology used for the main elements of the machine.

NOTE — In addition to terms used in the official ISO languages (English, French and Russian), this International Standard gives the equivalent terms in the German language; these are published under the responsibility of the member body for Germany (DIN). However, only the terms given in the official languages can be considered as ISO terms.

It deals only with the verification of the accuracy of the machine. It does not apply to the testing of the running of the machine (vibrations, abnormal noises, stick-slip motion of components, etc.) or to machine characteristics (such as speeds, feeds, etc.) which should generally be checked before the accuracy is tested.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 230-1 : 1986, *Acceptance code for machine tools — Part 1: Geometric accuracy of machines operating under no-load or finishing conditions.*

ISO 701 : 1976, *International gear notation — Symbols for geometrical data.*

ISO 1328 : 1975, *Parallel involute gears — ISO system of accuracy.*

3 Preliminary remarks

3.1 In this International Standard, the dimensions and the permissible deviations are expressed in millimetres and inches.

3.2 To apply this International Standard, reference should be made to ISO 230-1, especially for the installation of the machine before testing, warming up of spindles and other moving parts, description of measuring methods and recommended accuracy of testing equipment.

3.3 The sequence in which the geometrical tests are given is related to the sub-assemblies of the machine and this in no way defines the practical order of testing. In order to make the mounting of instruments or gauging easier, tests may be applied in any order.

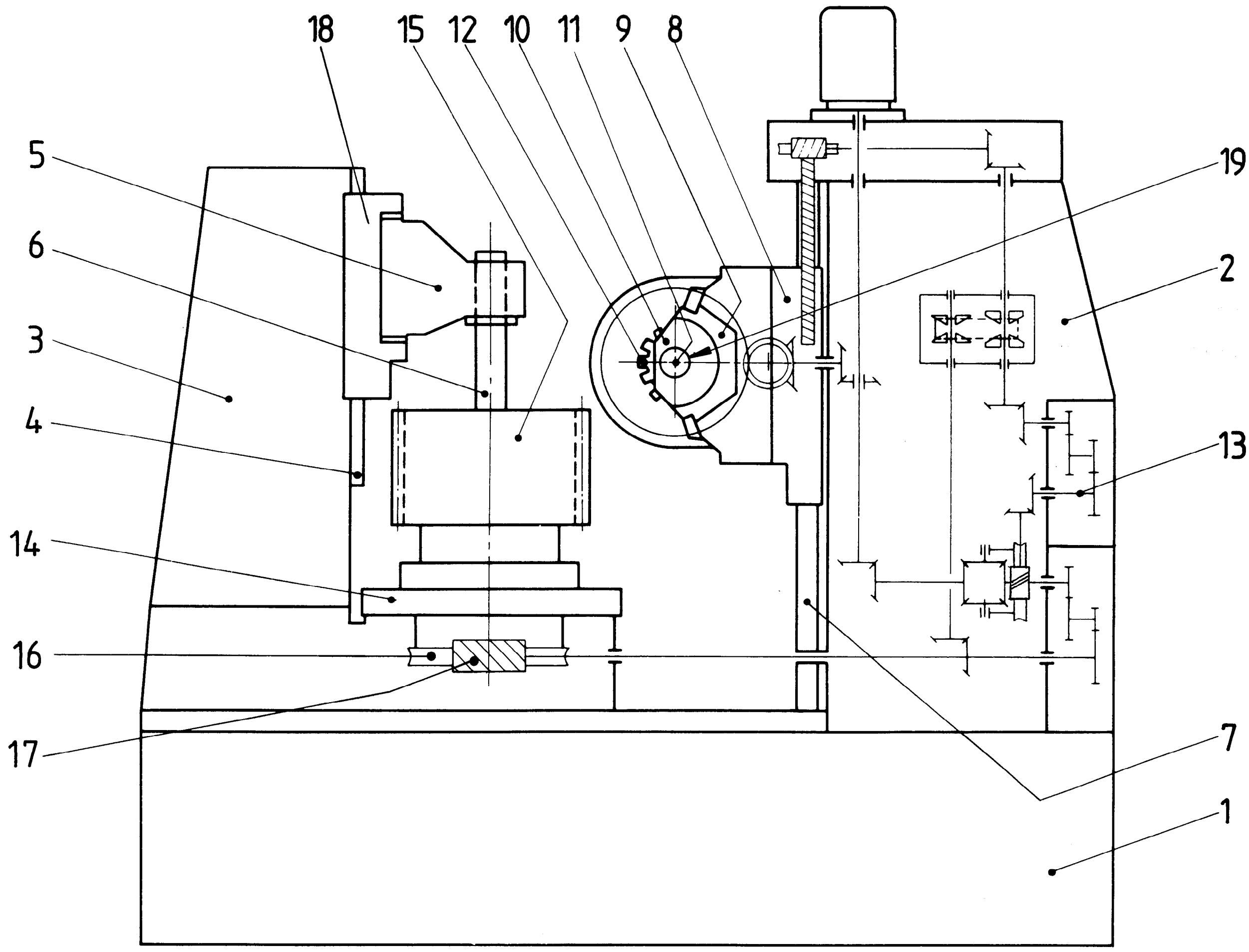
3.4 When inspecting a machine, it is not always possible, or necessary, to carry out all the tests described in this International Standard. It is up to the user to choose, in agreement with the manufacturer, those tests relating to the existing elements of the machine or to the properties which are of interest, but these tests are to be clearly stated when ordering a machine.

3.5 Practical tests shall be made with finishing cuts and not with roughing cuts which are liable to generate appreciable cutting forces. The actual feeds and speeds will be selected by the manufacturer to suit the particular machine.

3.6 When the tolerance is established for a measuring range different from that given in this International Standard (see ISO 230-1 : 1986, 2.311) it should be taken into consideration that the minimum value of tolerance is 0,005 mm (0,000 2 in).

3.7 The values using the formulae shall be rounded to the nearest 0,001 mm (0,000 1 in).

4 Terminology



Ref.	English language	French language	Russian language	German language
1	Bed	Banc	Станина	Bett
2	Column	Montant	Передняя стойка	Hauptständer
3	Work-steady column	Montant de la lunette	Задняя стойка с люнетом	Gegenhalterständer
4	Work-steady slideway	Glissière de la lunette	Направляющая люнета	Gegenhalterführung
5	Work-steady	Lunette	Люнет	Gegenhalterarm
6	Work arbor (clamping arbor)	Arbre porte-piece	Оправка	Aufspanndorn
7	Axial slideway	Glissière du chariot axial	Направляющая суппорта фрезы	Axialschlittenführung
8	Axial slide	Chariot axial	Суппорт фрезы	Axialschlitten
9	Tangential slide	Chariot tangentiel (ou porte-fraise)	Поперечный суппорт	Tangentialschlitten
10	Outboard bearing	Contre-palier du madrin porte-fraise	Подшипник оправки фрезы	Fräsdorn-Gegenlager
11	Axis of rotation of the hob spindle	Axe de la broche porte-fraise	Ось шпинделя	Drehachse des Werkzeugträgers
12	Hob	Fraise-mère	Фреза	Wälzfräser
13	Reference shaft	Arbre de référence	Эталонный вал	Bezugswelle
14	Work-table (-carrier; -spindle)	Plateau porte-pièce	Рабочий стол	Werkstückträger
15	Workpiece	Pièce	Обрабатываемая деталь	Werkstück
16	Index worm wheel	Roue de division	Делительное колесо	Teilschneckenrad
17	Index worm	Vis de division	Делительный винт	Teilschnecke
18	Work-steady slide	Chariot porte-lunette	Суппорт люнета	Gegenhalterschlitten
19	Hob arbor	Arbre porte-fraise	Фрезерная оправка	Fräserdorn

5 Symbols

For the purposes of this International Standard, the following symbols in addition to those given in ISO 701 apply.

5.1 Reference workpiece

d_u	reference diameter
m_{tu}	transverse module
P_{tu}	transverse diametral pitch
z_u	number of teeth

5.2 Test workpiece

b	face width
d	reference diameter
m	normal module
m_t	transverse module
P	normal diametral pitch, in reciprocal inches
P_t	transverse diametral pitch, in reciprocal inches
z	number of teeth
β	helix angle

5.3 Capacity of the machine

d_{max}	reference diameter of the largest workpiece that can be hobbed on the machine
$m_{0, max}$	maximum hob module
$P_{0, min}$	minimum diametral pitch of the hob, in reciprocal inches

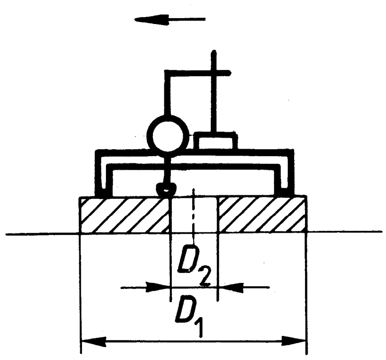
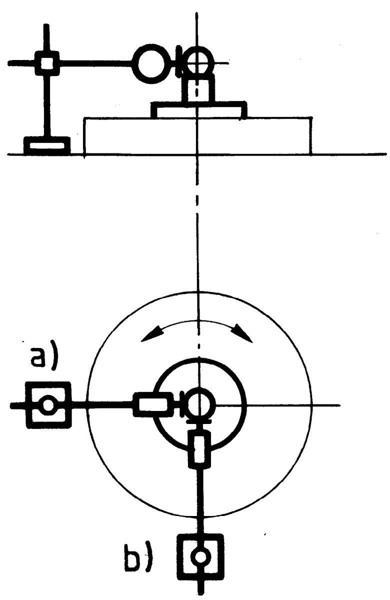
5.4 Accuracy of the machine or of the test gear

f_{dk}	high-frequency component of the angular transmission deviation
f_{dk0}	part of f_{dk} proportional to the transverse module of a reference or test workpiece
f_{dkT}	part of f_{dk} proportional to the reference diameter of a reference or test workpiece
f_{dl}	low-frequency component of the angular transmission deviation
$f_{dl, max}$	maximum amplitude (peak to peak) of the low-frequency component of the angular transmission deviation
$f_{f\beta}$	helix form deviation
$f_{H\beta}$	helix slope deviation
f_{pt}	single pitch deviation
f_{tk}	high-frequency component of the tangential linear transmission deviation
f_{tl}	low-frequency component of the tangential linear transmission deviation
f_{xk}	high-frequency component of the axial linear transmission deviation
f_{xl}	low-frequency component of the axial linear transmission deviation
F_d	angular transmission deviation
F_p	total cumulative pitch deviation
F_{pj}	cumulative pitch deviation
F_t	tangential linear transmission deviation
F_x	axial linear transmission deviation
F_α	total profile deviation

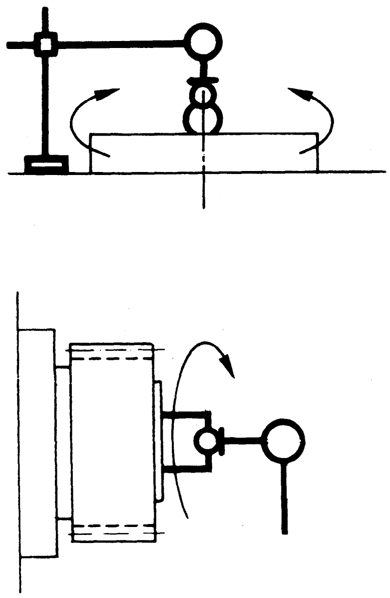
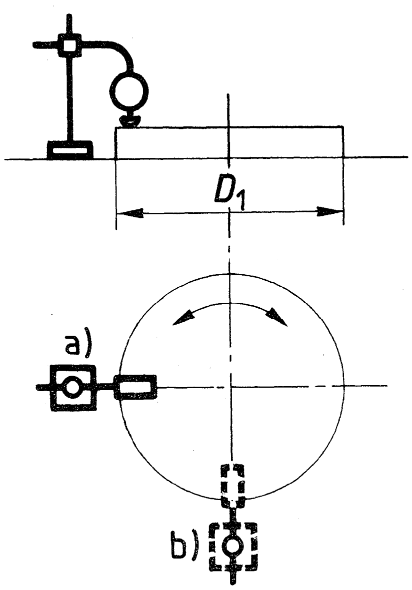
5.5 Additional symbols

p_1	number of periods of the cumulative pitch deviation defined in accordance with 8.2
s	length of arc on a reference circle
z_S	number of starts of the index worm
z_T	number of teeth of the index worm wheel

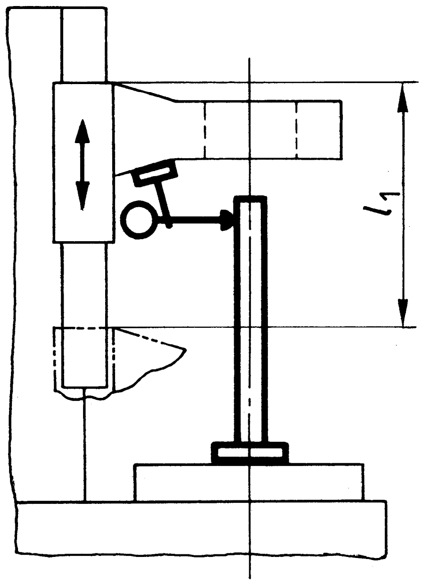
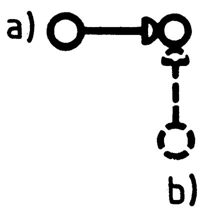
6 Geometrical tests

No.	Diagram	Object
		A — WORK-TABLE
G1		Measurement of the diametral straightness of the surface of the work-table
G2		Measurement of radial run-out of the axis of rotation of the work-table or work-spindle

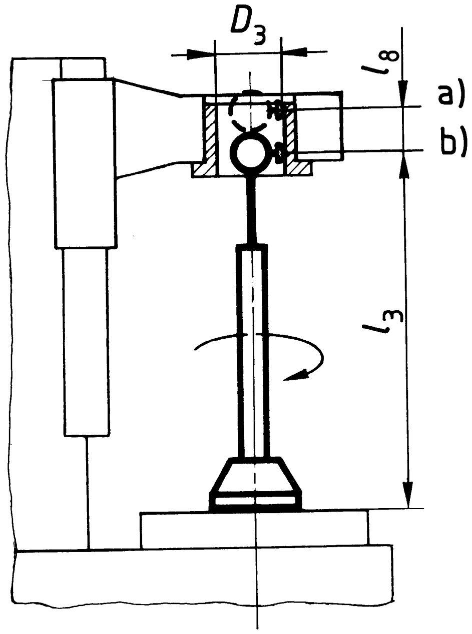
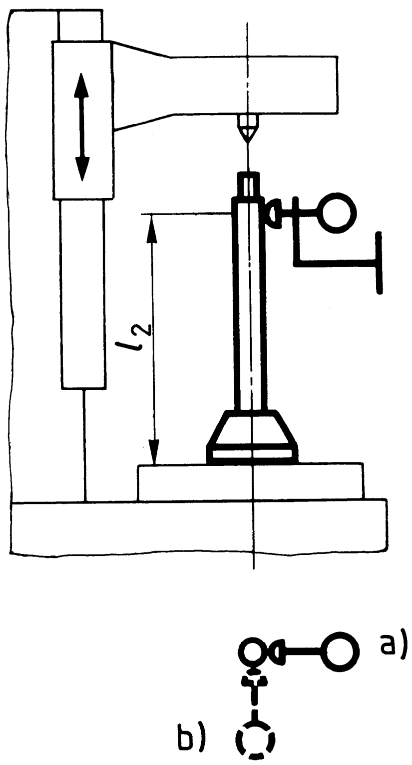
Permissible deviation		Measuring instruments	Observations and references to the ISO 230-1 : 1986 acceptance code
0,001 mm	0,000 1 in		
d, D, l, m in millimetres	$d, D, l, m, \frac{1}{P}$ in inches		
$6 + 0{,}6\sqrt{D_1 - D_2}$ Straight or concave	$2{,}36 + 1{,}19\sqrt{D_1 - D_2}$	Straightedge and dial gauge, level or other equipment	Subclauses 5.2 and 5.3 Trace the surface of the work-table with a precision dial gauge using the bridge-type straightedge as a reference. Machines without work-tables do not require this test. For machines up to 500 mm diameter work-table check the straightness on two diameters and on machines with a work-table greater than 500 mm on four diameters.
$4 + 0{,}1\sqrt{d_{max}}$	$1{,}57 + 0{,}2\sqrt{d_{max}}$	Flat-tipped dial gauge, ball, and special support or test cylinder	Subclause 5.612 Place two gauges, located 90° apart at a) and b) against the ball, perpendicular to the axis of rotation of the work-spindle. Adjust the ball on the support so that the variations of the indicator readings of both dial gauges during one revolution of the work-table will be as small as possible. The variations of the indicator readings at a) and b) shall be recorded as the measured radial run-out. Take measurements in both directions of rotation of the work-spindle at a) and b). The largest of the indicator reading variations shall be recorded as the measured radial runout. These measurements can also be made by using a test cylinder in place of the ball and special support.

No.	Diagram	Object	
G3		Measurement of periodic axial slip of the work-spindle	
G4		Measurement of camming of the work-table	

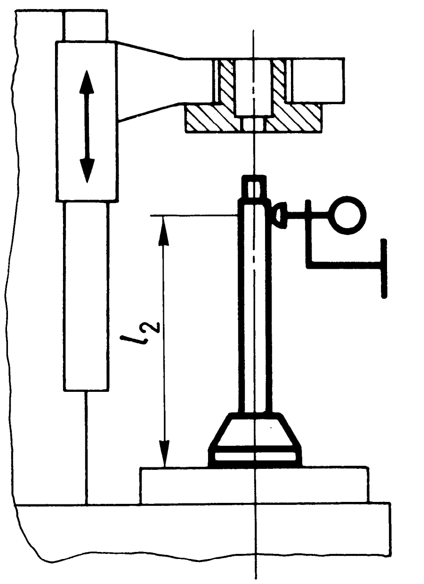
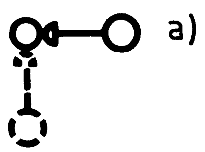
Permissible deviation 0,001 mm — d, D, l, m in millimetres	Permissible deviation 0,000 1 in — d, D, l, m, $\frac{1}{P}$ in inches	Measuring instruments	Observations and references to the ISO 230-1 : 1986 acceptance code
$4 + 0{,}06 \sqrt{d_{max}}$	$1{,}57 + 0{,}12 \sqrt{d_{max}}$	Flat-tipped dial gauge, ball and special support	Subclauses 5.622.1 and 5.622.2 Place the stylus of the dial gauge in alignment with the axis of rotation of the work-spindle and against the ball adjusted as in test G2. Take measurements in both directions of rotation of the work-spindle. On machines where the work arbor axis is horizontal, apply a force F, if necessary*), in order to eliminate the axial play in the bearing; the value of this force shall be specified by the manufacturer. *) Not necessary in the case of axially preloaded bearings.
$6 + 0{,}25 \sqrt{D_1}$	$2{,}36 + 0{,}5 \sqrt{D_1}$	Crown-tipped dial gauge	Subclause 5.632 Touch the work-table surface with a dial gauge successively at two points a) and b) located 90° apart on the largest possible measuring circle diameter (one measuring point a) or b) opposite the hob). Take measurements in both directions of rotation of the work-table. The largest of the indicator reading variations shall be recorded as the measured camming. On machines where the work arbor axis is horizontal, apply a force F, if necessary*), as in test G3. NOTE — It may be useful to put a flat block between the stylus and the table surface. *) Not necessary in the case of axially preloaded bearings.

No.	Diagram	Object
G5	  l_1 maximum working traverse of the work-steady	**B — WORK-STEADY** Measurement of parallelism of the work-steady movement with the axis of rotation of the work arbor

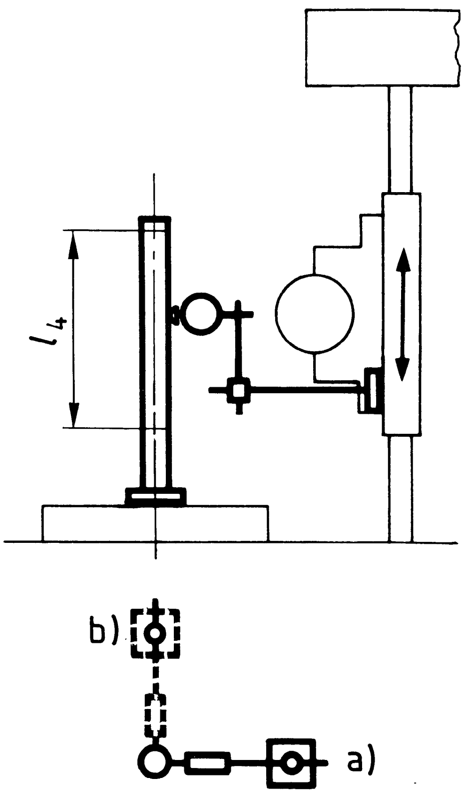
Permissible deviation		Measuring instruments	Observations and references to the ISO 230-1 : 1986 acceptance code
0,001 mm	0,000 1 in		
d, D, l, m in millimetres	$d, D, l, m, \frac{1}{P}$ in inches		
a)			Subclause 5.422.3
Permissible deviation at the free end of the test mandrel			Attach the dial gauge to the work-steady near the bore of the steady, and place the tip against the test mandrel in positions a) and b). Adjust the test mandrel to its position of mean radial run-out for each measuring direction.
towards the axis of the hob spindle:			
$8 + 0{,}8\sqrt{l_1}$	$3{,}15 + 1{,}59\sqrt{l_1}$		
in the opposite direction:		Crown-tipped dial gauge and cylindrical test mandrel	Take measurements at a) and b) over the full working traverse of the work-steady, with the work-steady slide clamped, if applicable.
$4 + 0{,}4\sqrt{l_1}$	$1{,}57 + 0{,}79\sqrt{l_1}$		
b)			Determine the mean of the variations of the indicator readings at a) and b) per spindle revolution. The variation of the mean values is the deviation of parallelism.
$6 + 0{,}5\sqrt{l_1}$	$2{,}36 + 0{,}99\sqrt{l_1}$		These measurements may also be taken with a recording instrument while the work arbor is rotating.

No.	Diagram	Object
G6.1	 l_3 maximum working height of the work-steady above the surface of the table l_8 distance between the two measuring planes D_3 diameter of the bush bore	Measurement of coincidence of the work-steady bush bore with the work arbor axis of rotation
G6.2	 l_2 distance between the measuring point and the surface of the table	**For machines with centres** Measurement of coincidence or alignment of the work-steady centre with the axis of rotation of the work arbor

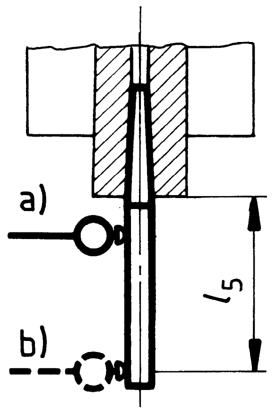
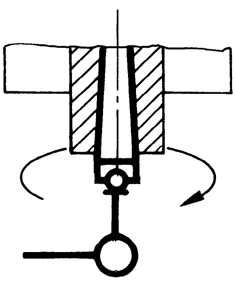
Permissible deviation 0,001 mm — d, D, l, m in millimetres	Permissible deviation 0,000 1 in — $d, D, l, m, \frac{1}{P}$ in inches	Measuring instruments	Observations and references to the ISO 230-1 : 1986 acceptance code
$6 + 0{,}6\sqrt{l_3}$	$2{,}36 + 1{,}19\sqrt{l_3}$	Crown-tipped dial gauge and its support	Subclause 5.442 If this test cannot be performed then test G6.3 shall be performed. Place the dial gauge and its support on the work-table and touch the inside of the steady bush bore which is placed at the maximum working height. Take measurements near the top and bottom ends of the steady bush bore in both directions of rotation of the work-table, in positions a) and b) at a distance of l_8 apart, with the work-steady clamped during the measurements, if applicable. The variation the readings (ignoring the effect of form deviations) divided by two is the deviation of the coaxiality. These permissible deviations apply to each of the two measurements. NOTE — If $\frac{l_8}{D_3} < 0{,}5$ and $l_8 \leqslant 80$ mm; $l_8 \leqslant 3{,}15$ in only one check at $l_3 + \frac{l_8}{2}$ is necessary.
a) Permissible deviation (offset) towards the hob spindle: $6 + 0{,}4\sqrt{l_2}$ in the opposite direction: $3 + 0{,}2\sqrt{l_2}$ b) Permissible deviation $6 + 0{,}4\sqrt{l_2}$	 $2{,}36 + 0{,}79\sqrt{l_2}$ $1{,}18 + 0{,}4\sqrt{l_2}$ $2{,}36 + 0{,}79\sqrt{l_2}$	Crown-tipped dial gauge, test mandrel or clamping arbor	Subclause 5.44 Place the stylus of the dial gauge against the clamping arbor or test mandrel at positions a) and b) at a distance l_2 from the work-table. This distance l_2 extends from the work-table to a point adjacent to the work-steady. Adjust the clamping arbor to its position of mean radial run-out for each measuring direction. Take measurements at a) and b) with the work steady set against the clamping arbor, and also with it separated from the clamping arbor. The work-steady shall be clamped during the measurements, if applicable. The variations of the indicator readings, caused by setting the work-steady against the clamping arbor, is the measured deviation. These measurements may also be taken while the work arbor is rotating. Determine the mean value of the variations of the indicator readings at a) and b) per work arbor revolution with the work-steady set against, and separated from, the clamping arbor. The difference of the mean values of the indicator readings is the measured deviation.

No.	Diagram	Object
G6.3	  l_2 distance between the measuring point and the surface of the table	Measurement of coincidence of the work-steady bush bore with the axis of rotation of the work arbor

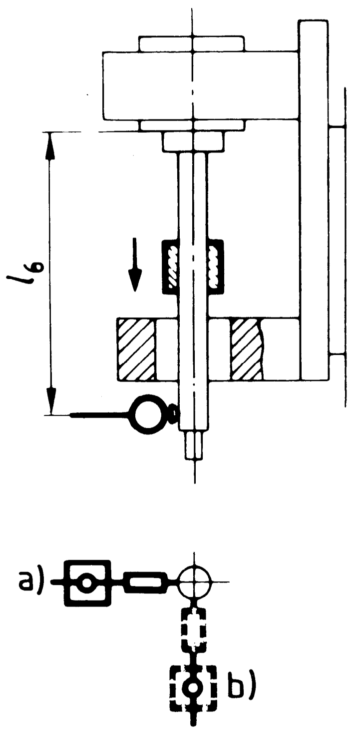
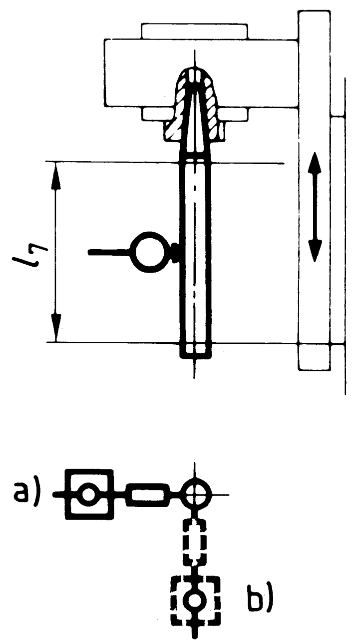
Permissible deviation 0,001 mm — d, D, l, m in millimetres	Permissible deviation 0,000 1 in — d, D, l, m, $\frac{1}{P}$ in inches	Measuring instruments	Observations and references to the ISO 230-1 : 1986 acceptance code
a) and b) $6 + 0{,}4\sqrt{l_2}$ For a), deviation (offset) only permissible towards the hob spindle. The readings shall not exceed the permissible deviation minus one-half of the play.	a) and b) $2{,}36 + 0{,}79\sqrt{l_2}$	Crown-tipped dial gauge, test mandrel or clamping arbor	Subclause 5.44 If the test G6.1 cannot be accomplished this test shall be performed. Place the stylus of the dial gauge against the aligned clamping arbor in positions a) and b) at a distance l_2 from the work-table. This distance l_2 extends from the work-table to a point adjacent to the work-steady. Adjust the clamping arbor to its position of mean radial run-out for each direction. Take measurements at a) and b) with the work-steady set against, and also with it separated from, the clamping arbor. If applicable, the work-steady shall be clamped against the column during the measurement. The variation of the reading of the dial gauge caused by setting the work-steady against the clamping arbor, plus one-half of the play between bore and journal, is the measured deviation. These measurements may also be taken while the clamping arbor is rotating.

No.	Diagram	Object
G7	 l_4 maximum traverse of the axial slide	C — AXIAL AND TANGENTIAL SLIDES Measurement of parallelism of the axial slide movement with the axis of rotation of the work-spindle

Permissible deviation		Measuring instruments	Observations and references to the ISO 230-1 : 1991 acceptance code
0,001 mm	0,000 1 in		
d, D, l, m in millimetres	$d, D, l, m, \frac{1}{P}$ in inches		
a)		Crown-tipped dial gauge and test mandrel	Subclause 5.422.2 Place the dial gauge on the axial slide and touch the test mandrel in two perpendicular planes a) and b). Adjust the test mandrel to its position of mean radial run-out. Take measurements in the two planes a) and b) along the full traverse of the axial slide and in both directions of displacement of this slide. On hobbing machines with oblique feed (Grant method), the tangential slideways shall be set to 0°. The variations of the indicator readings in planes a) and b) are the measured deviations. These measurements may also be taken while the work-spindle is rotating. Determine the mean value of the variations of the indicator readings in planes a) and b) per work-spindle revolution along the full traverse of the axial slide and in both directions of displacement of this slide. The variations of the mean values of the indicator readings are the measured deviations in a) and b).
Permissible deviation at end of test mandrel towards the axis of the hob spindle:			
$8 + 0,8\sqrt{l_4}$	$3,15 + 1,59\sqrt{l_4}$		
in the opposite direction:			
$4 + 0,4\sqrt{l_4}$	$1,57 + 0,79\sqrt{l_4}$		
b)			
$6 + 0,5\sqrt{l_4}$	$2,36 + 0,99\sqrt{l_4}$		
The deviations noted in planes a) and b) shall not exceed the permissible limits at any distance between the axes of the hob and work arbor.			

No.	Diagram	Object
G8	 l_5 half the maximum distance between the hob spindle nose and the middle of the outboard bearing of the hob arbor	Measurement of run-out of the mounting bore in the hob spindle: a) near the hob spindle nose; b) at a distance l_5 from the hob spindle nose.
G9		Measurement of periodic axial slip of the hob spindle

Permissible deviation		Measuring instruments	Observations and references to the ISO 230-1 : 1986 acceptance code
0,001 mm	0,000 1 in		
d, D, l, m in millimetres	$d, D, l, m, \frac{1}{P}$ in inches		
a) 6 b) $6 + 0{,}6\sqrt{l_5}$	a) 2,36 b) $2{,}36 + 1{,}19\sqrt{l_5}$	Crown-tipped dial gauge and test mandrel	Subclause 5.612 Take measurements in the two directions of rotation with the axis preferably set to the vertical position.
$4 + 0{,}6\sqrt{m_{0,\,max}}$	$1{,}57 + 1{,}19\sqrt{\frac{1}{P_{0,\,min}}}$ or $1{,}57 + 1{,}19\sqrt{m_{0,\,max}}$	Flat-tipped dial gauge, preloading device if necessary, test mandrel and ball	Subclause 5.622 Place the stylus of the dial gauge against the ball located in the centre hole of the test mandrel, and apply a force F, if necessary*), in order to eliminate the axial play in the bearing. The value of this force shall be specified by the manufacturer. Take measurements in both directions of rotation. *) Not necessary in the case of axially preloaded bearings.

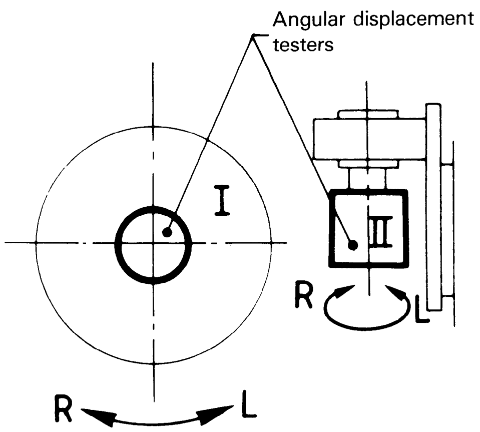
No.	Diagram	Object
G10	 l_6 distance between the measuring point adjacent to the free end of the hob arbor and the hob spindle nose	Measurement of coincidence of the outboard bearing with the hob spindle axis
G11	 l_7 maximum traverse of the tangential slide	Measurement of parallelism of the tangential slide movement with the axis of rotation of the hob spindle

Permissible deviation		Measuring instruments	Observations and references to the ISO 230-1 : 1986 acceptance code
0,001 mm	0,000 1 in		
d, D, l, m in millimetres	d, D, l, m, $\frac{1}{P}$ in inches		
a) and b) $6 + 0{,}5\sqrt{l_6}$ In a), deviation permissible only towards the axis of the work arbor	a) and b) $2{,}36 + 0{,}99\sqrt{l_6}$	Crown-tipped dial gauge, test bush, and hob arbor	Subclause 5.442 Place the stylus of the dial gauge against the hob arbor successively in two perpendicular planes a) and b) and as near as possible to the outboard bearing. The hob spindle should preferably be set to a vertical position. Adjust the hob arbor to its position of mean radial run-out for each measuring direction. Take measurements in positions a) and b) first without the test bush inserted in the outboard bearing, then with it inserted. The measured deviation is equal to the sum of the coincidence variation caused by inserting the test bush plus half the play between the test bush and the hob arbor. These measurements may also be taken while the hob spindle is rotating.
a) and b) $6 + 0{,}5\sqrt{l_7}$	a) and b) $2{,}36 + 0{,}99\sqrt{l_7}$	Crown-tipped dial gauge and test mandrel	Subclause 5.422.3 Place the stylus of the dial gauge against the test mandrel in two perpendicular planes a) and b). Adjust the mandrel to its position of mean radial run-out for each measuring direction. Take measurements in planes a) and b) along the full traverse, in both directions of displacement, of the tangential slide. The axis of the hob spindle shall if possible be set to a vertical position. If the tangential slide is clamped during hobbing, the measurements shall be taken in the clamped condition. The variations of the indicator readings in planes a) and b) are the measured deviations. These measurements may also be taken while the hob spindle is rotating.

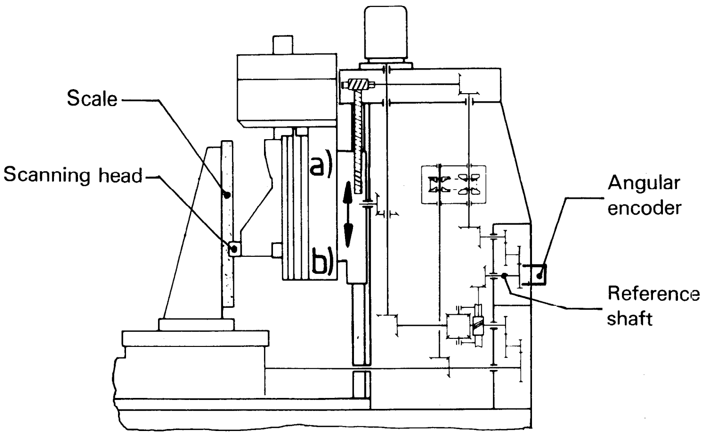
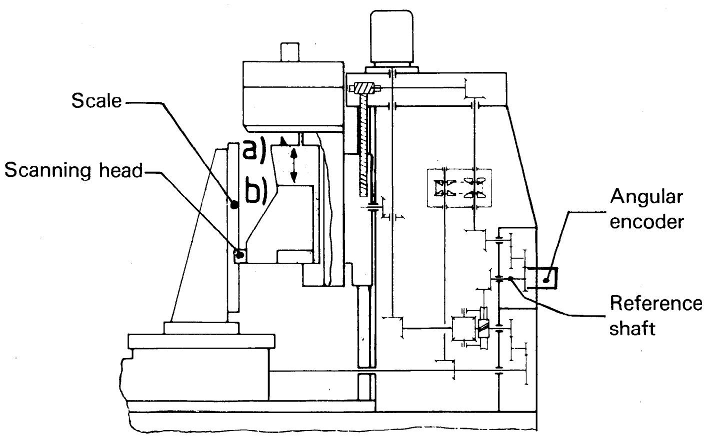
7 Kinematic tests

7.1 Description of the tests

Instead of the following kinematic tests, practical tests, see clause 8, may be carried out.

No.	Diagram	Object
K1		Rotation of the work-spindle relative to the rotation of the hob spindle

Permissible deviation		Measuring instruments	Observations and references to the ISO 230-1 : 1986 acceptance code
0,001 mm	0,000 1 in		
d, D, l, m in millimetres	$d, D, l, m, \frac{1}{P}$ in inches		
$f_{dl} = 1{,}13\sqrt{d_{u1}}$ $f_{dk1} = f_{dk2} = f_{dk}$ $f_{dk} = 5 + 1{,}5\sqrt{m_{0,\,max}}$	$f_{dl} = 2{,}24\sqrt{d_{u1}}$ $f_{dk} = 1{,}97 + 2{,}98\sqrt{\frac{1}{P_{0,\,min}}}$ or $f_{dk} = 1{,}97 + 2{,}98\sqrt{m_{0,\,max}}$	Angular transmission deviation measuring device	Attach angular displacement testers (I and II) to the work- and hob spindles. Take measurements in both directions of rotation of the work-spindle during continuous motion, under no-load conditions, with the hob spindle rotating in the direction preferably selected in operation and the machine set up for the reference workpiece ① or ② respectively. If the measured deviation f_{dk1} or f_{dk2} exceeds 80 % of the permissible deviation, repeat the measurements with the hob spindle rotating in the opposite direction (provided that the design of the machine permits this) to check that f_{dk1} and f_{dk2} do not have values over the permissible deviation. Reference workpiece ① : $d_{u1} = \frac{2}{3} d_{max};\ m_{tu1} = \frac{1}{3} m_{0,\,max};\ P_{tu1} = 3\,P_{0,\,min}$ $z_{u1} = \frac{d_{u1}}{m_{tu1}} = \frac{2d_{max}}{m_{0,\,max}}$ or $z_{u1} = 2\,d_{max}\,P_{0,\,min}$ Reference workpiece ② : $d_{u2} = \frac{1}{3}\,d_{max};\ m_{tu2} = m_{0,\,max};\ P_{tu2} = P_{0,\,min}$ $z_{u2} = \frac{d_{u2}}{m_{tu2}} = \frac{1}{3}\,\frac{d_{max}}{m_{0,\,max}}$ or $z_{u2} = \frac{1}{3}\,d_{max}\,P_{0,\,min}$ where $d_{u1}, m_{tu1}, z_{u1}, P_{tu1}$ and $d_{u2}, m_{tu2}, z_{u2}, P_{tu2}$ are the reference diameter, transverse module, number of teeth and transverse diametral pitch of the reference workpieces ① and ② respectively.

No.	Diagram	Object
K2	 l_4 maximum traverse of the axial slide	Movement of the axial slide relative to the rotation of the reference shaft in the slide drive
K3	 l_7 maximum traverse of the tangential slide	Movement of the tangential slide relative to the rotation of the reference shaft in the slide drive

Permissible deviation		Measuring instruments	Observations and references to the ISO 230-1 : 1986 acceptance code
0,001 mm	0,000 1 in		
d, D, l, m in millimetres	$d, D, l, m, \frac{1}{P}$ in inches		
$f_{xl} = 1{,}2\sqrt{l}$ $0 \leqslant l \leqslant l_4$ The measured deviation shall not exceed the permissible deviation on any length l. The component of the tangential linear transmission deviation is not taken into account. $f_{xk} = 6 + 0{,}6\sqrt{m_{0,\max}}$	$f_{xl} = 2{,}38\sqrt{l}$ $f_{xk} = 2{,}36 + 1{,}19\sqrt{\frac{1}{P_{0,\min}}}$ or $f_{xk} = 2{,}36 + 1{,}19\sqrt{m_{0,\max}}$	Linear transmission deviation measuring device	Attach the scale of the measuring device to the bed or column of the machine, the scanning head to the axial slide, and the angular encoder to the reference shaft. Take measurements with the axial slide moving in both directions a) and b) under no-load conditions. Hobbing machines with oblique feed (Grant method) and special machines for cutting worm wheels do not require this test. A laser interferometer may be used instead of the scale and the scanning head.
$f_{tl} = 1\sqrt{l}$ $0 \leqslant l \leqslant l_7$ The measured deviation shall not exceed the permissible deviation on any length l. The component of the axial linear transmission deviation is not taken into account. $f_{tk} = 6 + 0{,}6\sqrt{m_{0,\max}}$	$f_{tl} = 1{,}98\sqrt{l}$ $f_{tk} = 2{,}36 + 1{,}19\sqrt{\frac{1}{P_{0,\min}}}$ or $f_{tk} = 2{,}36 + 1{,}19\sqrt{m_{0,\max}}$	Linear transmission deviation measuring device	Attach the scale of the measuring device to the bed or column of the machine, the scanning head to the tangential slide, and the angular encoder to the reference shaft. Take measurements with the tangential slide moving in both directions a) and b) under no-load conditions. Hobbing machines with oblique feed (Grant method) and machines without tangential feed do not require this test. A laser interferometer may be used instead of the scale and the scanning head.

7.2 Notes relating to kinematic tests

7.2.1 Test K1

The accuracy of the rotation of the work-spindle relative to the rotation of the hob spindle is determined by the magnitude of the form and positional deviations of all elements in the gear train between the work-spindle and the hob spindle. As all these elements rotate, their deviations will recur periodically in accordance with their respective frequencies of rotation, so that the deviation of the relative turning motion will be always the sum of several periodic deviation components. For practical reasons, it is advisable to separate the low-frequency component from the higher frequency components.

7.2.1.1 angular transmission deviation, F_d: Deviation of the angular position of the work-spindle from its desired position determined by the respective position of the hob spindle and the setting of the machine, i.e. the transmission ratio of the gear train between hob spindle and work-spindle which in this case is assumed to be free from deviation. The deviation is measured as the length of arc on the reference circle of a reference workpiece.

7.2.1.2 low-frequency component, f_{dl}, of the angular transmission deviation: Component caused by the low-frequency component of the tangential composite deviation of the index worm wheel in the installed position and the instability of the axis of rotation of the work-spindle in the measuring plane.

7.2.1.3 high-frequency component, f_{dk}, of the angular transmission deviation: Component caused by deviations of the angular position of the elements rotating at higher speeds than the work-spindle. The lower frequency limit of these high-frequency components equals half the frequency of rotation of the slowest running shaft (the work-spindle excluded).

The high-frequency component of the angular transmission deviation includes components which are proportional to the diameter and to the transverse module of the workpiece. For this reason, the procedure specified for test K1 is convenient for taking measurements with a small module and a large diameter as well as with a large module and a small diameter (reference workpieces ① and ② respectively).

If the measuring method for test K1 is impracticable for one or the other of the reference workpieces for reasons inherent in the machine or the necessary testing equipment (e.g. working range of the measuring instruments), values other than those specified for d_{u1} and m_{tu1} or d_{u2} and m_{tu2} respectively may be used for d_u and m_{tu}. The tolerances shall then be calculated as detailed below.

Deviating from the requirements for test K1, the angular transmission deviation of single-purpose machines may be measured with respect to the reference diameter and transverse module corresponding to those under which the machine will work in actual operation.

If the machine is tested on the basis of a setting corresponding to a reference workpiece having the reference diameter d_u and the transverse module m_{tu}, f_{dku} and f_{dlu} are as follows:

$$f_{dku} = 0{,}6\, f_{dk} \left(\frac{m_{tu}}{m_{0,\max}} + 2 \frac{d_u}{d_{ma}} \right) \text{ in the metric version,}$$

or

$$f_{dku} = 0{,}6\, f_{dk} \left(\frac{P_{0,\min}}{P_{tu}} + 2 \frac{d_u}{d_{\max}} \right) \text{ in the inch version}$$

and

$$f_{dlu} = 0{,}9 \sqrt{s} \text{ in the metric version, or}$$

$$f_{dlu} = 1{,}79 \sqrt{s} \text{ in the inch version.}$$

The requirements for f_{dlu} have to be met for any length of arc from $s = 0$ to $s = d_u \cdot \pi/2$.

NOTE — For checking over half the circumference ($s = d_u \cdot \pi/2$), the limit deviation is

$$f_{dlu,\max} = 1{,}13 \sqrt{d_u} \text{ in the metric version, or}$$

$$f_{dlu,\max} = 2{,}24 \sqrt{d_u} \text{ in the inch version.}$$

The relationship between the instantaneous values of the angular transmission deviation is

$$F_{du} = f_{dlu} + f_{dku}$$

The permissible cumulative pitch deviation F_{pj} over a sector of j pitches shall be calculated as follows:

$$F_{pj} = F_d = f_{dl} + f_{dk}$$

$F_{pju} = 0{,}9 \sqrt{s} + f_{dku} = 1{,}6 \sqrt{j m_{tu}} + f_{dku}$ in the metric version, or

$F_{pju} = 1{,}79 \sqrt{s} + f_{dku} = 3{,}17 \sqrt{j/P_{tu}} + f_{dku}$ in the inch version.

The testing equipment for F_d, f_{dl} and f_{dk} consists of testing devices with optical, magnetic or other index plates as well as seismic devices.

As the reference workpieces only provide reference values for checking the angular transmission deviation between the work-spindle and the hob spindle, the module $m_{tu1} = \frac{m_{0,\max}}{3}$ and the transverse diametral pitch $P_{tu1} = 3P_{0,\min}$ may deviate from a standardized value of modules, or diametral pitch, respectively, and the numbers of teeth z_{u1} and z_{u2} need not be integers. However, if the testing equipment employed only permits the use of integral values of z_{u1} and z_{u2}, the module of the reference workpiece shall be selected so that d_{u1} and d_{u2} will have the required values. In this case the tolerances for f_{dku} of the reference workpiece shall be calculated in accordance with the formula stated above. This applies, above all, to machines on which the modules that can be hobbed are large in relation to the maximum workpiece diameter of the machine.

7.2.2 Tests K2 and K3

7.2.2.1 linear transmission deviations, F_x or F_t: Deviation of the position of the axial slide or tangential slide from its desired position.

The desired position is determined by the transmission ratio of the gear train between slide and reference shaft (which, in this

case, is assumed to be free from deviations) and the respective angular position of the reference shaft in the slide drive. The reference shaft may be any shaft in the drive of the slide (axial or tangential) between the feed spindle and the differential. It could, for example, be the shaft of a differential change gear. The reference shaft may be chosen by the manufacturer.

7.2.2.2 low-frequency components, f_{xl} and f_{tl}, of the linear transmission deviation: Components caused mainly by lead deviations, deformation of the feed screw, and tilting, i.e. variation of inclination of the axial or tangential slide to the column while moving.

7.2.2.3 high-frequency components, f_{xk} and f_{tk}, of the linear transmission deviation: Components caused by angular position deviation of the faster rotating elements between reference shaft and feed screw. The lower frequency limit of these high-frequency components is equal to half the rotary frequency of the slowest running shaft (feed screw included).

Apart from the above, high-frequency components of the linear transmission deviation may also result from geometric defects of components of the feed screw itself.

7.2.3 Tests K1, K2 and K3

The course of the deviation shall be plotted on a diagram as a function of the length l (tests K2 and K3) or the arc s (test K1, see figure 1).

The curves of the positive and negative permissible deviations should be drawn on transparent paper on the same scale for both vertical and horizontal coordinates.

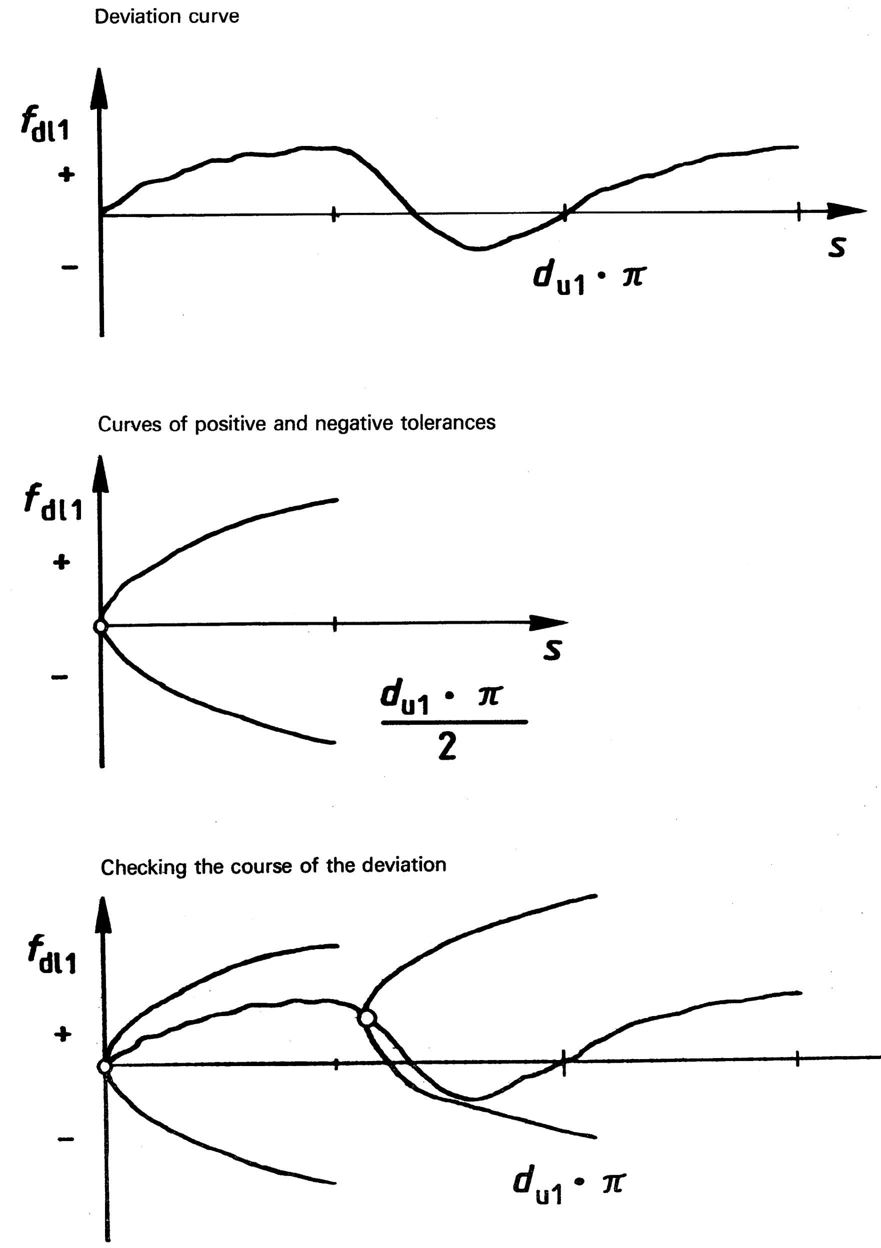


Figure 1 — Example for test K1

If the origin of the coordinates of this tolerance curve is then shifted along the measured curve in such a manner that the l or s axes remain parallel, the deviation curve shall always lie within the zone defined by the two tolerance curves.

8 Practical tests

When the cutting of a test gear is agreed between the manufacturer and the user as indirect verification of the accuracy of the machine, all details including, in particular, the design and the material of the test gear, hob and all hobbing data shall be fixed at the time the order is placed.

8.1 Introduction

Material of the test gear, hob and hobbing data shall be selected so as to produce a surface quality which is sufficient for measuring purposes. The agreement shall also include the testing equipment to be employed. Measurement of the total profile deviation F_α is not practicable because any deviation inherent in the hob would affect the results.

In the case of hobbing machines with oblique feed (Grant method), the helix form deviation $f_{f\beta}$ is primarily a function of the deviations of the hob and its mounting. For this reason, the helix form deviation of test gears hobbed by the Grant method cannot be a criterion for the acceptance or rejection of the machine. For the same reason, the tangential composite deviation test and especially the radial composite deviation test are not practicable either.

The circular pitch should preferably be measured on the machine or alternatively the gear blank shall be provided with a centring rim of high geometrical accuracy to ensure proper mounting for cutting and measurement.

The circular pitch of cylindrical gears may be measured in the area adjacent to one of the faces of the gear. In this area the gear shall be hobbed without axial feed.

8.2 Design of the test gear

The test gear shall comply with the followng design criteria:

$$d = \frac{2}{3} d_{\max} \text{ and } d \leqslant 4\,000 \text{ mm or } d \leqslant 160 \text{ in}$$

$$20^\circ \leqslant \beta \leqslant 30^\circ$$

$$10 m_{0,\max} \leqslant b \leqslant 350 \text{ mm or}$$

$$10/P_{0,\min} \leqslant b \leqslant 14 \text{ in}$$

In order to enable the evaluation of the test results for machines with a high number of teeth in the main index worm wheel, the calculation of the number of teeth of the test gear according to the following formulae is recommended. The number of teeth per period of the cumulative pitch deviation will then be about 9 to 11. Instead of verifying the geometrical and kinematic accuracy directly by means of measurements taken on the machine itself, such verification may be performed indirectly by measuring a test gear.

The number of teeth z of the work is given by the formula

$$z = z_T - p_1$$

For $\frac{z_T}{11} \geqslant 3{,}5$, p_1 is the integer nearest to $\frac{1}{11} z_T$, but if $\frac{1}{11} z_T < 3{,}5$ then $p_1 = 4$ and $z = z_T - 4$.

8.3 Tolerances of the test gear

8.3.1 General

Tolerances are calculated in 0,001 mm in the metric version and in 0,000 1 in in the inch version.

The values of m, d, and b are in millimetres in the metric version and the values of $\frac{1}{P}$, d and b are in inches in the inch version.

8.3.2 Part of f_{dk} proportional to the reference diameter of a reference or test workpiece, f_{dkT} (see 5.4)

f_{dkT} is as follows:

$$f_{dkT} = \frac{d}{d_{\max}} \left(6 + 1{,}8 \sqrt{m_{0,\max}} \right) \text{ in the metric version,}$$

or

$$f_{dkT} = \frac{d}{d_{\max}} \left(2{,}36 + 3{,}57 \sqrt{\frac{1}{P_{0,\min}}} \right) \text{ in the inch version}$$

where

f_{dkT} can be determined as the component of the cumulative pitch deviation with p_1 periods per table revolution. This component has approximately the same amplitude as the angular transmission deviation component with z_T periods per table revolution (see figures 2 and 4).

8.3.3 Low-frequency component of the angular transmission deviation, f_{dl} (see 5.4)

f_{dl} is as follows:

$$f_{dl} = 1{,}6 \sqrt{j \cdot m_t} \quad \text{in the metric version}$$

$$f_{dl} = 3{,}17 \sqrt{\frac{j}{P_t}} \quad \text{in the inch version}$$

where

f_{dl} can be determined as the low-frequency component of the cumulative pitch deviation. For checking the course of f_{dl}, the number j of pitches has to be valid from $j = 1$ to $\frac{1}{2} z$ for even numbers of teeth and to $\frac{1}{2} (z-1)$ for odd numbers of teeth.

8.3.4 Cumulative pitch deviation, F_{pj}, and total cumulative pitch deviation, F_p, of the workpiece

The cumulative pitch deviation and total cumulative pitch deviation shall also be limited by the deviations f_{dk} and f_{dl}. This results in the following tolerances:

$$F_{pj} = f_{dk} + f_{dl}$$

$$F_{pj} = 0{,}6 f_{dk} \left(\frac{m_t}{m_{0,max}} + 2 \frac{d}{d_{max}} \right) + 1{,}6 \sqrt{j \cdot m_t}$$

and

$$F_p = f_{dk} + f_{dl,max}$$

$$F_p = 0{,}6 f_{dk} \left(\frac{m_t}{m_{0,max}} + 2 \frac{d}{d_{max}} \right) + 1{,}13 \sqrt{d}$$

in the metric version, or

$$F_{pj} = 0{,}6 f_{dk} \left(\frac{P_{0,min}}{P_t} + 2 \frac{d}{d_{max}} \right) + 3{,}17 \sqrt{\frac{j}{P_t}}$$

and

$$F_p = 0{,}6 f_{dk} \left(\frac{P_{0,min}}{P_t} + 2 \frac{d}{d_{max}} \right) + 2{,}24 \sqrt{d}$$

in the inch version.

8.3.5 Helix slope deviation, $f_{H\beta}$ (see 5.4)

The helix slope deviation shall be limited by

$f_{H\beta} = 8 + \sqrt{b}$ in the metric version,

or

$f_{H\beta} = 3{,}15 + 1{,}98 \sqrt{b}$ in the inch version.

8.3.6 Comments on tolerances of the test gear

If it is not possible, especially in the case of large machines, to make a test workpiece with a number of teeth according to 8.2, the manufacturer and the user shall agree upon a special test gear to verify the accuracy of the machine.

For special workpieces for which the design is not in accordance with this International Standard, generally valid tolerances cannot be stated, especially in cases in which high cutting speeds and feeds are applied.

If, in the curve of the total cumulative pitch deviation, the low-frequency component and the component with p_1 periods cannot be separated easily then a test workpiece with $z = z_T$ teeth may be hobbed additionally. The permissible total cumulative pitch deviation for this workpiece is $f_{dl,max}$ as mentioned above.

8.4 Remarks

From the diagram (see figure 2) of the permissible high-frequency angular transmission deviation components f_{dk1} (with m_{tu1} and d_{u1}) and f_{dk2} (with m_{tu2} and d_{u2}), the permissible high-frequency deviation component f_{dk} (see figure 2) for any diameter d, and module m_t can be read off. Alternatively the formula f_{dku} can be used (see 7.2.1.3).

The machine diagram shown is valid for a hobbing machine (d_{max} = 600 mm and $m_{0,max}$ = 6 mm), the deviations of which are equal to the permissible deviations (f_{dk1} and f_{dk2}). For smaller deviations the actual machine diagram can also be drawn.

The transmission deviations of a gear hobbing machine are copied on to the gears produced. As these transmission deviations (see figure 2) have a dependency on diameter, which is different from the dependency which the single pitch deviation (f_{pt}) has according to ISO 1328, it is not possible to say that a machine will produce one particular class of gear with respect to f_{pt}. The high-frequency component of the angular transmission deviation may be taken from the machine diagram. One part of the high-frequency angular transmission deviation depends on the module m_t (f_{dk0}) and the other part depends on the diameter d (f_{dkT}).

Figure 3 shows the drives which cause f_{dk0} and f_{dkT}. The high-frequency component of the angular transmission deviation f_{dkT} most likely has $p = z_T$ periods per work revolution (see figure 4). With the number of teeth of the test gear mentioned above ($z = z_T - p_1$), f_{dkT} can be determined from the measurement of the cumulative pitch deviation. In fact the cumulative pitch deviation shows p_1 periods, the amount of which is approximately equal to the value of the high-frequency component of the angular transmission deviation with $p = z_T$ periods, i.e. f_{dkT}. As this p_1 period does not actually exist in the angular transmission deviation, this curve is called the virtual transmission deviation.

To facilitate the separation of the two components f_{dl} and f_{dk}, it is not permissible to determine the course of the cumulative pitch deviation by means of a span measurement when f_{dk} has to be determined.

Hobbing machines with multi-start index worm drives have one component of f_{dkT} with $p = z_T$ periods and another component with index worm rotation frequency of $\frac{z_T}{z_S}$ periods. In this case the evaluation of the cumulative pitch deviation presents more problems than for machines with single-start index worm drives. When the fraction $\frac{z_T}{z_S}$ does not result in an integer, the cumulative pitch deviation measurement does not produce a useful result.

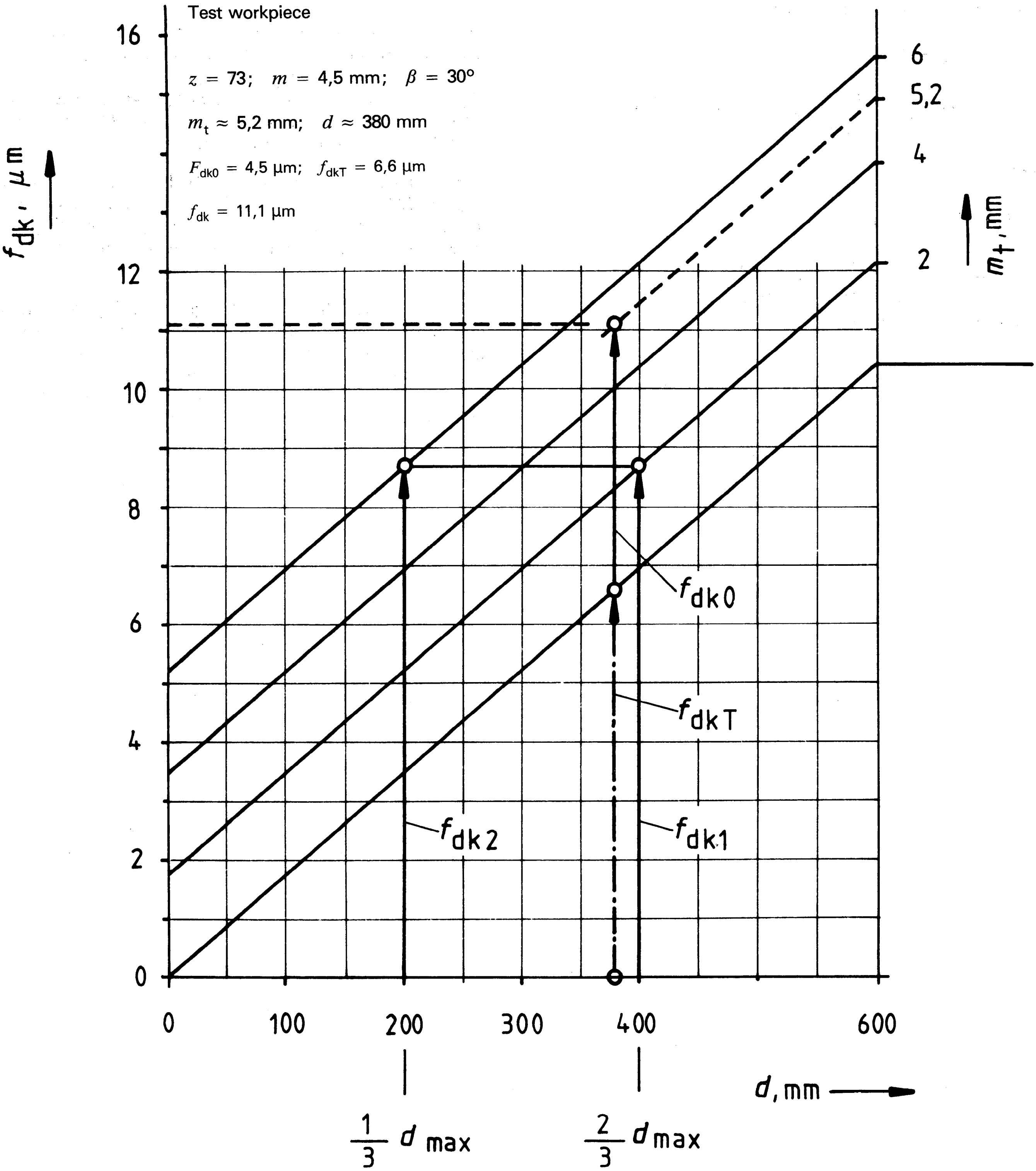


Figure 2 — High-frequency component f_{dk} of the angular transmission deviation of a hobbing machine having a capacity of d_{max} = 600 mm and $m_{0,\,max}$ = 6 mm

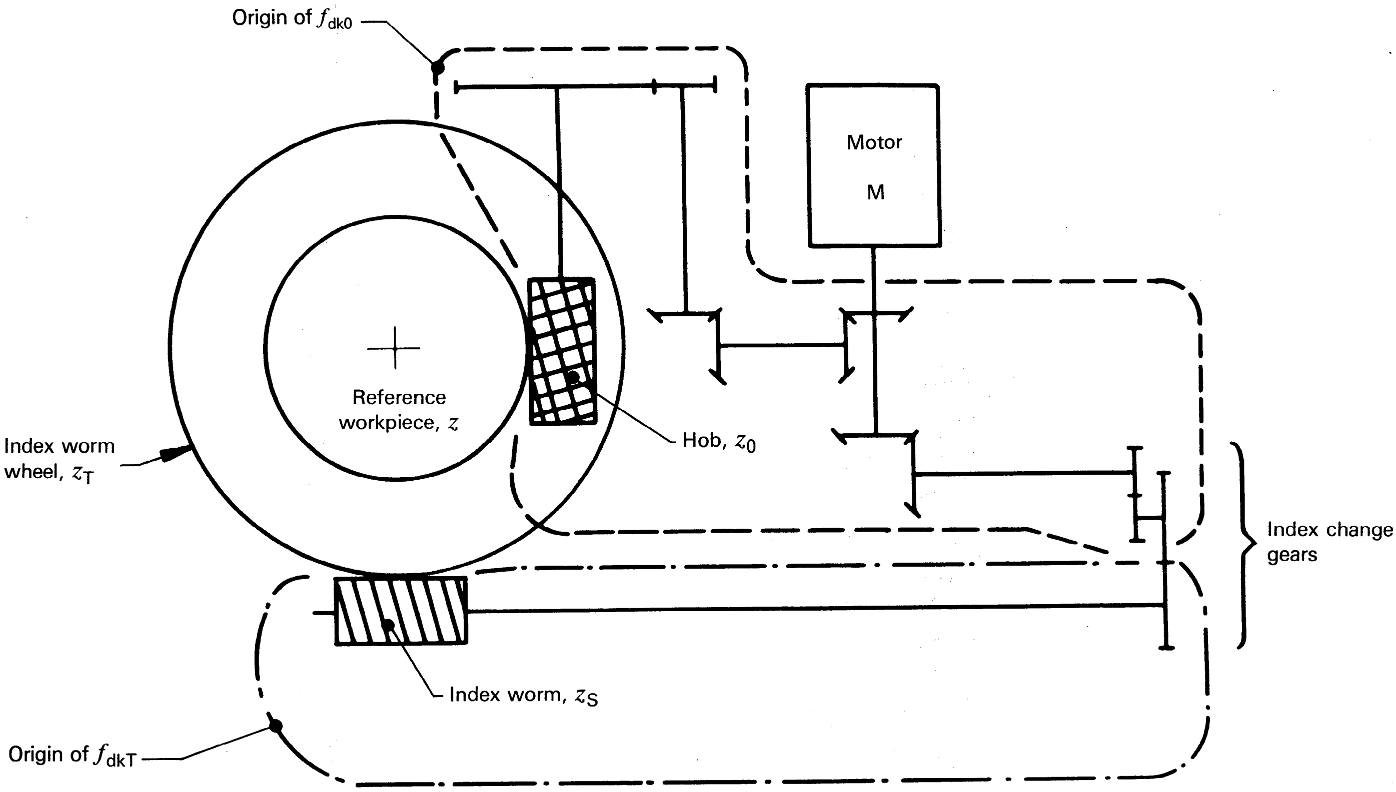
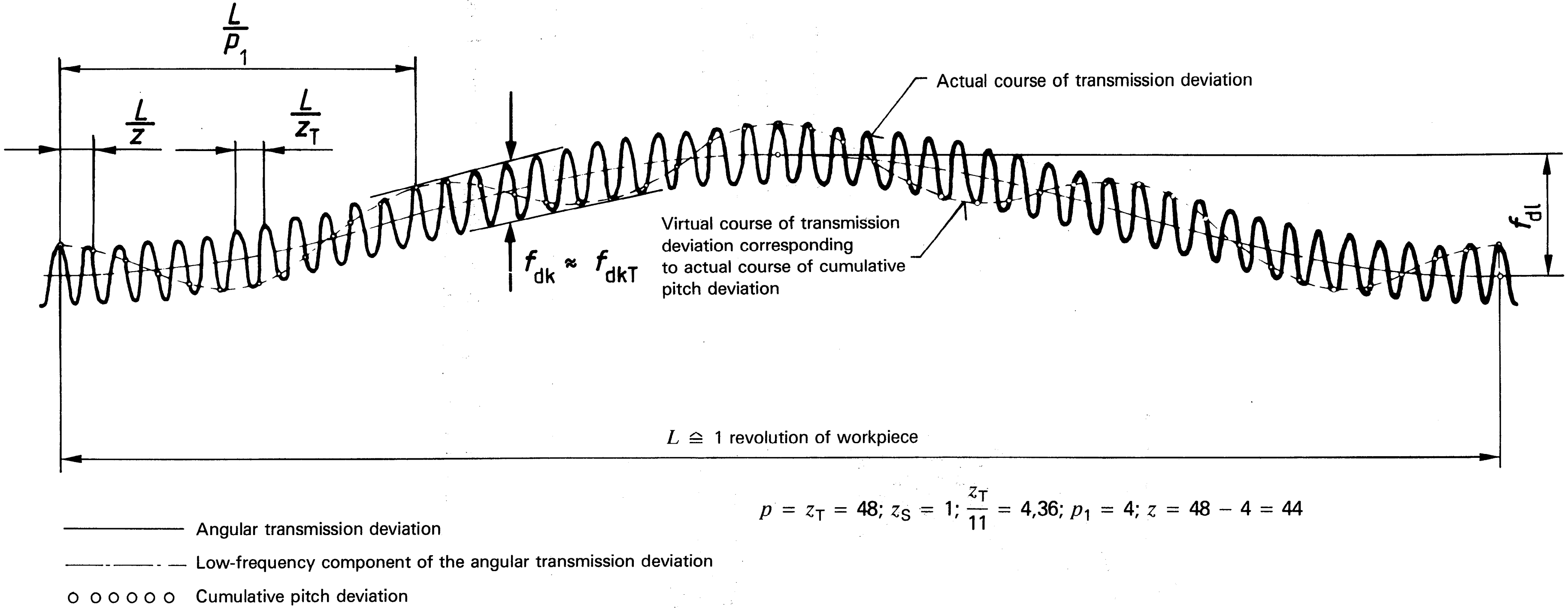


Figure 3 — Angular transmission drive of a gear hobbing machine — Origin of the high-frequency components of the angular transmission deviation



$p = z_T = 48$; $z_S = 1$; $\frac{z_T}{11} = 4{,}36$; $p_1 = 4$; $z = 48 - 4 = 44$

Figure 4 — Example for the determination of the angular transmission deviation component at index worm rotation frequency

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